

**Intrinsic Channel Properties, Scattering Mechanisms, Quantum Transport Properties in  
Transition Metal Dichalcogenides**

by

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DISSERTATION

Submitted to the Graduate School

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2008

MAJOR: Physics

Approved by:

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Advisor

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This is a dedication.

“The fact that we live at the bottom of a deep gravity well, on the surface of a gas covered planet going around a nuclear fireball 90 million miles away and think this to be normal is obviously some indication of how skewed our perspective tends to be.”

— Douglas Adams, *The Salmon of Doubt: Hitchhiking the Galaxy One Last Time*

## **ABSTRACT**

### **Intrinsic Channel Properties, Scattering Mechanisms, and Quantum Transport Properties in Transition Metal Dichalcogenides**

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Major: Physics

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Abstract here

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# List of Symbols

Symbol	Description	Unit
$\mathbf{A}$	vector potential	$\text{V s m}^{-1}$
$A$	area	$\text{cm}^2$
$A^*$	Richardson's constant	$\text{A s}^{-1} \text{K}^2$
$B$	magnetic field	T
$C$	capacitance	F
$E$	electric field	$\text{V m}^{-1}$
$E$	energy	eV (J)
$E_{\text{F}}$	Fermi energy	eV
$E_g$	bandgap energy	eV
$\hat{\mathbf{H}}$	Hamiltonian	eV (joule)
$I$	current	A
$I_{\text{ds}}$	drain current	A
$L$	length	$\mu\text{m}$
$L$	channel length	$\mu\text{m}$
$m$	mass	kg
$m^*$	effective mass	kg
$n$	carrier density	$\text{cm}^{-2}$
$n$	charge carrier density	$\text{C cm}^{-2}$
$\hat{\mathbf{p}}$	momentum operator	$\text{kg m s}^{-1}$
$R$	resistance	$\text{k}\Omega \mu\text{m}$ ( $\Omega$ )
$R_c$	contact resistance	$\text{k}\Omega \mu\text{m}$
$R_H$	Hall coefficient	$\text{m}^3 \text{C}^{-1}$
$\hat{\mathbf{s}}$	spin operator	$\hbar$ (J s)

$T$	temperature	K
$V$	voltage	V
$V_{\text{bg}}$	backgate voltage	V
$V_{\text{ds}}$	drain voltage	V
$V_{\text{H}}$	Hall voltage	V
$w$	channel width	$\mu\text{m}$
$\mu$	mobility	$\text{cm}^2 \text{V}^{-1} \text{s}^{-1}$
$\mu_{\text{B}}$	magnetic moment	$\text{eV T}^{-1}$
$\mu_e$	electron mobility	$\text{cm}^2 \text{V}^{-1} \text{s}^{-1}$
$\mu_{\text{FE}}$	field-effect mobility	$\text{cm}^2 \text{V}^{-1} \text{s}^{-1}$
$\mu_{\text{H}}$	Hall mobility	$\text{cm}^2 \text{V}^{-1} \text{s}^{-1}$
$\mu_p$	hole mobility	$\text{cm}^2 \text{V}^{-1} \text{s}^{-1}$
$\rho$	resistivity	$\Omega \text{cm}$
$\rho_{xx}$	longitudinal resistivity	$\Omega$
$\rho_{xy}$	transverse resistivity	$\Omega$
$\sigma$	conductivity	$\mu\text{S}$
$\sigma_{xx}$	longitudinal conductivity	$\mu\text{S}$
$\sigma_{xy}$	transverse conductivity	$\mu\text{S}$
$\tau$	scattering time	s
$\tau_{\text{q}}$	quantum scattering time	s
$\Phi_{\text{B}}$	barrier height	eV
$\Phi_{\text{B}n}$	electron barrier height	eV
$\Phi_{\text{B}p}$	hole barrier height	eV
$\Phi_{\text{M}}$	metal work function	eV
$\Phi_{\text{S}}$	semiconductor work function	eV
$\chi$	electron affinity	eV
$\chi_{\text{S}}$	semiconductor electron affinity	eV
$\omega_c$	cyclotron frequency	Hz

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# List of Physical Constants

Symbol	Quantity	Value
$\mu_B$	Bohr magneton	$9.274\,009 \times 10^{-24} \text{ J T}^{-1}$ $5.788\,381 \times 10^{-5} \text{ eV T}^{-1}$ $e\hbar/2m_e$ (atomic units)
$k_B$	Boltzmann's constant	$1.380\,66 \times 10^{-23} \text{ J K}^{-1}$
$\epsilon_0$	Dielectric constant	$8.854\,18 \times 10^{-12} \text{ A}^2 \text{ s}^4 \text{ kg}^{-1} \text{ m}^{-3}$ $8.617\,34 \times 10^{-5} \text{ eV K}^{-1}$
$e$	Elementary charge	$1.602\,18 \times 10^{-19} \text{ C}$
$m_e$	Electron mass	$9.109\,383 \times 10^{-31} \text{ kg}$
eV	Electron volt	$1.602\,18 \times 10^{-19} \text{ J}$
$c$	Speed of light	$2.997\,92 \times 10^8 \text{ m s}^{-1}$
$h$	Planck's constant	$6.626\,07 \times 10^{-34} \text{ J s}$
$\mu_0$	Permeability in vacuum	$1.256\,63 \times 10^{-6} \text{ m kg s}^{-2} \text{ A}^{-2}$ $4\pi \times 10^{-7} \text{ m kg s}^{-2} \text{ A}^{-2}$
$\hbar$	Reduced Planck's constant	$1.054\,57 \times 10^{-34} \text{ J s } (h/2\pi)$
$k_B T$	Thermal energy	$0.025\,86 \text{ eV } (T = 27^\circ\text{C})$ $0.025\,26 \text{ eV } (T = 20^\circ\text{C})$
$R_{K-90}$	von Klitzing constant	$25\,812.807\,455\,55 \, \Omega$

*Source:* CODATA Recommended Values of the Fundamental Physics Constants: 2014, Mohr *et al.*<sup>1</sup>

# Conversion Factors

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Conversion Factors	
1 Å	= 0.1 nm
	= $10^{-4}$ μm
	= $10^{-8}$ cm
	= $10^{-10}$ m
1 μm	= $10 \times 10^4$ Å
	= $10^3$ nm
	= $10^{-4}$ cm
	= $10^{-6}$ m
1 eV	= $1.60218 \times 10^{-19}$ J

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Powers of Ten

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$10^{24}$	yotta	Y
$10^{21}$	zetta	Z
$10^{18}$	exa	E
$10^{15}$	peta	P
$10^{12}$	tera	T
$10^9$	giga	G
$10^6$	mega	M
$10^3$	kilo	K
$10^2$	hecto	h
$10^1$	deka	da
$10^{-1}$	deci	d
$10^{-2}$	centi	c
$10^{-3}$	milli	m
$10^{-6}$	micro	$\mu$
$10^{-9}$	nano	n
$10^{-12}$	pico	p
$10^{-15}$	femto	f
$10^{-18}$	atto	a
$10^{-21}$	zepto	z
$10^{-24}$	yocto	y

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# Acronyms

**SB** Schottky barrier

# Chapter 1

## Chapter Title

### 1.1 Section Title

Contents here with Schottky barrier (SB). i



## Chapter 2

# Chapter Title

### 2.1 Section Title

## Chapter 3

# Chapter Title

### 3.1 Section Title

## Chapter 4

# Chapter Title

### 4.1 Section Title

# References

- [1] PJ Mohr, DB Newell, and BN Taylor. Codata recommended values of the fundamental constants 2014,(2015). *arXiv preprint arXiv:1507.07956*, 2015.